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AUTHOR Tudge, Jonathan
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ABSTRACT

The aim of this study was to assess the extent to which collaboration with a more competent peer aids children's ability to solve mathematical balance beam problems under feedback and no-feedback conditions. Subjects were 61 children whose pretest scores on 14 balance beam problems that allowed reliable assessment at five increasingly sophisticated levels of thinking were at rule level two or three. Target children were randomly assigned to one of three treatment groups. Children were paired with another child whose thinking was at the same or a higher level or were not paired at all. Pair members took turns predicting the movements of the beam which would result from the placing of weights at various distances from the fulcrum. If pair members disagreed in their predictions, they were left alone to discuss the problem and arrive at one answer. Half the children received immediate feedback on their joint solution; half received no feedback. It was hypothesized that: (1) children who worked with a partner would improve more than those who had no partner; (2) children who received feedback would improve more than those who did not; and (3) children whose partner was more competent and who received feedback would improve the most. The second hypothesis was supported by findings of posttests administered a week and a month after the treatment. Only in the absence of feedback did children suffer from the lack of a partner. (RH)

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Collaborative problem solving in the zone of proximal development

Jonathan Tudge

Child Development and Family Relations

University of North Carolina at Greensboro

PS 019132

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Introduction

Vygotsky (1978, 1987) emphasized that social interaction plays a crucial role in a child's cognitive development. In particular, he argued that interaction is most likely to prove beneficial when it occurs between a child and a partner (whether an adult or another child) who has greater competence in the task the child is trying to solve, and when assistance is provided within the child's "zone of proximal development." This zone comprises the difference between what the child can accomplish independently and what he or she can achieve with assistance.

Research based on Vygotsky's thinking has demonstrated that children are more likely to accomplish more in the process of collaborating with an adult (e.g., Wertsch, 1979) or with another peer (e.g., Forman & Cazden, 1985). While it is undoubtedly true that these results support Vygotsky's position, a further critical component of his theory is that the improved thinking displayed during the collaborative process itself should be "appropriated" (Leont'ev, 1981; Rogoff, 1990) or "internalized" (Vygotsky, 1987) by the child for use in subsequent individual performance. As Vygotsky wrote with reference to the results of interaction between a teacher and child, when the child subsequently solves a problem independently: "...he continues to act in collaboration, even though the teacher is not standing near him. ... This help--this aspect of collaboration--is invisibly present. It is contained in what loods from the outside like the child's independent solution of the problem" (Vygotsky, 1987, p. 216). However, with few exceptions (for example, Ellis & Rogoff, 1982; Gauvain & Rogoff, 1989; Radziszewska & Rogoff, 1989; Tudge, 1989) children have not been tested after the dyadic sessions to ascertain the extent to which they have appropriated the more competent way of

thinking.

Goal

The goal of this research was to assess the extent to which collaboration with a more competent peer aids children's subsequent individual ability to solve mathematical balance beam problems under conditions of feedback and no feedback. Previous research (Tudge, in press), suggested that when problems were only somewhat in advance of the child and the partner only somewhat more competent, feedback alone was sufficient to bring about development, even for children who had no partner. In this study, therefore, the problems were more difficult and the degree of partner's competence was systematically varied.

Methodology

Materials: A mathematical balance beam (see Figure 1) was used, in which 4 pegs were equally placed on each side of the central fulcrum. Weights were placed (differing both in number and distance from the fulcrum) on the beam, and children were asked to predict the beam's movement. Children were given 14 different problems to solve, varying in ease of solution. The pattern of predictions to these problems allows reliable assessment of 5 different and increasingly sophisticated levels of thinking or "rules." For details of the rules, see Tudge (1989).

Subjects consisted of 168 1st-3rd graders. Both to ensure comparability between the treatment groups in terms of pretest rule and to prevent children's improvment being limited by reaching ceiling, only children whose pretest rule was 2 or 3 were used in these analyses (61 children).

Pretest: All children were pretested individually.

Treatment: Approximately one week following the pretest, target children whose pretest rule was either 2 or 3 were randomly assigned to one of the following treatment groups:

a) paired with another child whose thinking was at the same level;

b) paired with a partner whose thinking was at a higher level;

c) not paired at all.

All pairs consisted of same age, same gender dyads, and dyads were formed from children from the same classroom. Pair members took turns to predict the movement of the beam, when weights were placed at differing distances from the fulcrum. If pair members disagreed in their predictions, they were left alone to discuss the problem and arrive at one answer. Half the children received immediate feedback to their joint solution (supports holding the beam in place were removed); half received no feedback, and simply proceeded to the next problem.

Posttest 1: One week after the treatment, all children were re-tested individually.

Posttest 2: One month after the treatment, all children were again tested individually.

Hypotheses

The overall assumption was that providing assistance within a child's zone of proximal development would be most easily accomplished by providing that child immediate feedback to his or her solution in conjunction with a more competent partner who could help to explain the movement of the beam. Specific hypotheses were as follows:

1. Children who worked with a partner would improve more than those who had

no partner;

2. Children who received feedback would improve more than those who did not;

3. Children whose partner was more competent and who received feedback would improve the most.

Results

Hypothesis 1 was not supported. On average, children who had been paired showed a somewhat greater improvement from pretest rule than those who had not been paired but these differences were not significant either at the time of the first posttest (Paired Mean 0.6, SD 1.43, Not paired Mean 1.04, SD 1.22, $F_{1,58} = 1.13$, $p < .3$) or at the time of the second posttest (Paired Mean 0.86, SD 1.27, Not paired Mean 0.70, SD 2.06, $F_{1,56} = 0.10$, $p < .8$). (The mean scores presented are the differences between the pretest rule used and the rule used at the time of the posttest.)

Hypothesis 2 was supported. On average, children who received feedback improved more than those who did not and this difference was significant both at the time of the first posttest (Feedback Mean 1.42, SD 1.26, No Feedback Mean 0.50, SD 1.07, $F_{1,58} = 9.35$, $p < .005$) and at the time of the second posttest (Feedback Mean 1.20, SD 1.63, No Feedback Mean 0.45, SD 1.06, $F_{1,56} = 4.32$, $p < .05$).

Hypothesis 3 was not supported. The results are presented in Tables 1 and 2, and indicate that when children received feedback the presence of a partner, whether more competent or not, was of no benefit; on average all children, whether paired or not, improved about the same. This was as true at the time of the first posttest (Table 1) as at the second posttest (Table 2),

except that at the second posttest children who had not been paired actually showed somewhat greater improvement than all others. However, in the absence of feedback, the presence of a partner proved somewhat helpful; children with no partner actually declined somewhat from their pretest score, whereas those with a partner improved approximately half a rule on average. However, this difference did not reach statistical significance either at the time of the first posttest ($F_{1,28} = 2.69$, $p < .12$) or at the second posttest ($F_{1,27} = 2.39$, $p < .14$).

However, before concluding that these data do not support Vygotsky's theory, it is necessary to provide a more fine-grained assessment of the influence of competence, for one could argue that a partner who is only slightly more competent than the target child might not be sufficiently able to provide much assistance. A second set of analyses was therefore conducted, which differentiated the partners in terms of how far in advance of the target child they were.

When the pair received feedback, a target child who collaborated with a child who was a good deal more competent (3 rules higher) improved more than all others. This was equally true at the first and second posttest (see Tables 3 and 4). In the absence of feedback, children whose partners used a rule either 2 or 3 above improved the most. These differences were close to significant at the time of the first posttest ($F_{4,55} = 2.42$, $p = .06$), but were not at the time of the second posttest ($F_{4,53} = 0.80$, $p < .6$).

Conclusions

There is only limited support for the hypothesis that social interaction with a more competent peer leads to cognitive growth. Collaboration with a

much more competent peer appears to be beneficial, but for the most part the clearest benefit related simply to receiving feedback from the materials. With feedback, the presence of a much more competent partner appears to have been of help, although being paired with a partner who was not much more competent proved less beneficial than being paired with no partner at all. Only in the absence of feedback did children suffer from the lack of a partner.

These data provide room for thought about the concept of the zone of proximal development. Whether working with a somewhat more competent partner on problems placed slightly in advance of the target child (Tudge, in press) or on problems some distance in advance of the target child with partners varying in terms of their greater competence (this study), no clear benefits of collaboration were found.

However, from a Vygotskian perspective, working within a child's zone of proximal development is more than simply pairing that child with a more competent partner--it is a matter of the more advanced partner actively working with the less advanced one to arrive at greater shared understanding. This implies, at the very least, that the more competent child should provide information at a higher level in a way that is accessible to and understandable by the less competent child. As Vygotsky stated with regard to interaction between a teacher and a child: "The teacher, working with the school child on a given question, explains, informs, inquires, corrects, and forces the child himself to explain (Vygotsky, 1987, pp. 215-216). What is essential in this process is that collaboration in working out the solution to the problem includes the <u>active</u> participation of both the more and the less competent partner, working on making sense together.

The data presented here provide no indication of the extent to which this type of sharing of information actually occurred in the course of the interactions. Coding of the videotaped records of the paired sessions is currently proceeding, and analysis of approximately 1/4 of the data suggests that it is by no means a common occurence for the more competent partner to provide justifications of reasoning that are likely to assist the target child. However, as Vygotsky suggested, when the partner does provide this type of help it appears to be the case that the target child is most likely to improve in his or her thinking, and for that improvement to still be in evidence a month later.

These data clearly support the view that children benefit greatly from seeing the results of their problem-solving attempts and are able to learn from their errors. Indeed, this type of feedback seems in some cases to outweigh any benefits that might accrue from working with a partner. In fact, these data suggest that the presence of a partner may, in some circumstances, actually be a hindrance--children who simply received feedback but who had no partner improved far more than anticipated, although not as much as those whose partner was a good deal more competent. Moreover, having a partner with whom to discuss the problems appears to be beneficial if feedback is not provided.

At present, it seems clear that simply pairing a target child with another who is more competent does not <u>necessarily</u> lead either to collaboration within the target's child zone of proximal development or to greater advance than pairing him or her with a partner who is not more competent, or even with no-one at all--at least when feedback is provided.

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Table 1

THE EFFECT OF COMPETENCE (at time of 1st posttest)

Condition	M	SD	N	T[a]
Feedback				
More competent partner	1.48	1.29	21	5.25***
Partner same rule	1.20	1.10	5	2.45+
No partner	1.40	1.52	5	2.06
No feedback				
More competent partner	0.58	1.07	19	2.36*
Partner same rule	0.83	1.17	6	1.75
No partner	-0.20	0.84	5	-0.53

[a] Difference from 0 (no change from pretest rule)

+ $p < .10$

* $p < .05$

*** $p < .005$

Table 2

THE EFFECT OF COMPETENCE (at time of 2nd posttest)

Condition	M	SD	N	T[a]
Feedback				
More competent partner	1.15	1.53	20	3.36***
Partner same rule	1.00	1.00	5	2.24+
No partner	1.60	2.61	5	1.37
No feedback				
More competent partner	0.61	1.14	18	2.26*
Partner same rule	0.50	0.84	6	1.46
No partner	-0.20	0.84	5	-0.53

[a] Difference from 0 (no change from pretest rule)

+ $p < .10$

* $p < .05$

*** $p < .005$

Table 3

THE EFFECT OF DEGREES OF COMPETENCE (1st posttest)

Condition	M	SD	N	T[a]
Feedback				
Partner 3 rules higher	3.00	.	4	.
Partner 2 rules higher	1.13	1.36	8	2.35*
Partner 1 rule higher	1.11	1.05	9	3.16**
Partner same rule	1.20	1.10	5	2.45+
No partner	1.40	1.52	5	2.06
No feedback				
Partner 3 rules higher	1.00	1.41	4	1.41
Partner 2 rules higher	0.86	0.90	7	2.52*
Partner 1 rule higher	0.13	0.19	8	0.36
Partner same rule	0.83	1.17	6	1.75
No partner	-0.20	0.84	5	-0.53

[a] Difference from 0 (no change from pretest rule)

+ $p < .10$

* $p < .05$

** $p < .01$

Table 4

THE EFFECT OF DEGREES OF COMPETENCE (2nd posttest)

Condition	M	SD	N	T[a]
Feedback				
Partner 3 rules higher	2.50	1.00	4	5.00**
Partner 2 rules higher	0.38	1.77	8	0.60
Partner 1 rule higher	1.25	1.04	8	3.42**
Partner same rule	1.00	1.00	5	2.24+
No partner	1.60	2.61	5	1.37
No feedback				
Partner 3 rules higher	0.75	1.71	4	0.88
Partner 2 rules higher	0.83	1.17	6	1.75
Partner 1 rule higher	0.38	0.92	8	1.16
Partner same rule	0.50	0.84	6	1.46
No partner	-0.20	0.84	5	-0.53

[a] Difference from 0 (no change from pretest rule)

+ $p < .10$

** $p < .01$